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Cover: Mycorrhizal *Hebeloma* fruiting on container lodgepole pine seedling

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Abstract

Forty species (67 isolates) of ectotrophic mycorrhizal fungi were grown at various pH levels and temperatures on agar medium. Optimum pH for growth ranged from 4 to 7; eight isolates grew over a range of seven pH units. None of the fungi grew at a pH greater than 9. Optimum temperature for growth ranged from 15 to 30°C with 45 isolates growing best at 25°C. Only *Sphaerosporella brunnea* grew at 35°C.

Résumé

Quarante espèces (67 isolats) de champignons mycorhiziens ectotrophes ont été cultivés sur gélose à des pH et températures variés. Leur pH optimal de croissance variait entre 4 et 7; huit isolats se sont, toutefois, développés dans un intervalle de pH de sept unités. Aucun champignon n'a poussé à un pH supérieur à 9. Par ailleurs, la température optimale de croissance variait entre 15 et 30 °C; elle était de 25 °C pour 45 isolats. Seul *Sphaerosporella brunnea* s'est développé a 35 °C.

Introduction

Ectomycorrhizal fungi are beneficial symbionts of forest trees in that they transfer nutrients and water to plants (Skinner and Bowen 1974; Melin and Nilsson 1950). Some fungi are more efficient in obtaining nutrients and water for the plant (Marx 1980), perhaps because they have rhizomorphs which are transporting vehicles (Brownlee *et al.* 1983). Another possibility is that certain fungi are better suited to grow or survive in a particular forest soil.

Until recently, selection of mycorrhizal fungi for nursery inoculation and subsequent outplanting trials was limited because the growth requirements for many of the fungi were not known. Improved growing and culturing techniques have increased fungus availability and selection could be based on the physiological characteristics of candidate fungi that may improve seedling survival or growth. Few physiological studies have been made on large numbers of ectomycorrhizal fungi. Mexal and Reid (1973) reported variation in growth under water stress for *Suillus luteus* (Fr.) S.F. Gray and *Thelephora terrestris* (Ehrh.) Fr. and confirmed tolerance to low water potential of *Cenococcum graniforme* (Sow.) Ferd. and Winge. Marx and Zak (1965) showed how laboratory manipulation of pH affected root colonization and subsequent enhancement of seedling growth by several fungi. Littke *et al.* (1984) examined the nitrogen physiology of *Hebeloma crustuliniforme* in culture and Rygiewicz *et al.* (1984 a, b) examined uptake of nitrogen by ectomycorrhizae formed by this fungus on three conifers. Studies such as these were done *in vitro* because of the complexity of natural soil, but the results might be used to select fungi suited to particular planting sites. Recently Hung and Trappe (1983) studied pH preferences of ten fungi and noted differences not only among species but also among fungus strains. Hacskaylo *et al.* (1965) studied the preferred temperature range of six species of mycorrhizal fungi and again found wide variations.

About 1978, studies were begun at the Pacific Forestry Centre to determine the effect of ectotrophic mycorrhizae on survival and growth of outplanted conifer seedlings. Physiological information was needed on a wide range of mycorrhizal fungi to determine the candidate that would be most beneficial to outplanted stock. The purpose of the research reported here was to determine the pH and temperature requirements for growth of a large number of mycorrhizal fungi which could be used in subsequent experiments on seedling growth and survival.

Materials and Methods

Sixty-seven cultures representing 40 species of fungi were obtained by isolation from sporocarps collected in British Columbia, or they were obtained from other researchers (Appendix I). Cultures were maintained by transferring monthly and incubating in darkness at 20°C. The medium used in both the pH and temperature growth range experiments was a modified Melin-Norkrans agar (Marx and Zak 1965) which was modified further by adding 1.5 g of tryptone per litre of medium.

To determine the effect of pH on growth of the fungi, pH of the medium was adjusted from 2 to 10 at intervals of approximately one pH unit by adding the required amounts of either 1N HCl or 1N NaOH to 1 litre amounts of cooled (45°C) medium immediately before pouring it into 9-cm diameter petri plates. Each plate was center inoculated with a 6-mm agar plug cut from 4-week-old, actively growing (same medium as above) cultures of the test fungus. The pH of the medium was determined using a flat-membrane combination electrode before the plates were inoculated, and again when the final growth measurements were made. Growth (mm) was determined by measuring the colony diameter of five replicate plates per treatment either after 4 weeks incubation in darkness at 20°C or when the fungus growth in any particular treatment completely covered the medium.

The procedures for the temperature range experiment were the same as for the pH experiment except that the pH of the medium (5.7) was not adjusted and cultures were incubated at 5°C intervals between 5 and 35°C. Data for both experiments were subjected to analysis of variance and the significance of treatment differences was determined using the Student-Newman-Keuls multiple range test (Steel and Torrie 1980).

Results

Detailed results including the significance ($p = 0.05$) of treatment mean differences are given in Appendixes II and III for the pH and temperature experiments, respectively. Table 1 summarizes the results of both experiments.

Growth of all the fungi was affected by pH to varying degrees; the optimum pH ranged from 4 to 7 (Table 1) . Three groups were recognized: fungi that grew best at only one pH, over a range of two adjacent pH units, or over a range of three adjacent pH units. Included in the latter were three *Suillus lakei* isolates and one isolate each of *Suillus tomentosus* and *Suillus brevipes* which had a double optimum (pH 4 and 6). The ability to grow, even slowly, over a range of pH levels also varied. Most of the fungi (45 isolates) grew over a range of four to five pH units. Only eight fungi grew over a range of seven pH units. Numerous isolates were tolerant to extreme acid or alkaline conditions. Of the six isolates that grew at pH 2, four were strains of *Suillus tomentosus*. The others were a strain of *S. brevipes* and *Rhizopogon vinicolor*. None of these fungi grew at a pH greater than 7. Six fungi grew at pH 9, including two isolates of *Hebeloma crustuliniforme*, both isolates of *Clitocybe nebularis* and isolates of *C. suaveolens* and *Lactarius uvidus*. No fungi grew at a pH greater than 9.

The optimum temperature for growth of the fungi ranged from 15 to 30°C (Table 1). Most isolates (46) grew best at either 20 or 25°C. Only one isolate each of *Armillaria ponderosa* and *Cortinarius violaceus* grew equally well at three temperatures. There were also differences in the ability to grow over a range of temperatures. Thirteen isolates grew over the wide range of six temperatures while eight grew over a range of only three temperatures. Only *Hygrophorus agathosmus* did not grow above 20°C. and only *Sphaerosporella brunnea* grew at 35°C.

Discussion

Using a solid medium in petri dishes allowed many fungi to be tested quickly for growth at various pH levels and temperatures. Fast growing fungi had to be assessed a few days after inoculation because they soon reached the edge of the plates while very slow growers had very little measurable differences after 4 weeks. Extending the incubation period was of no benefit because the medium began to dry out. Both very fast growing and very slow growing fungi, however, could be evaluated.

Results of the pH experiment agreed with results reported by Hung and Trappe (1983). Many isolates grew equally well over a range of pH levels and the double peak (at pH 4 and 6) reported for *Suillus lakei* occurred with five *Suillus* isolates, i.e., three *S. lakei*, one *S. tomentosus* and one *S. brevipes*. Results of the temperature experiment agreed with those reported by Hacskaylo (1965) and also demonstrated growth variability among and within species. Optimum and extreme temperatures varied as much as 10°C. and could not be related to origin of the fungus. The results should help in selecting fungi for experiments on planting sites with extremes in temperatures.

Criteria for the selection of symbiotic fungi have not been well defined. It is logical to select a fungus well adapted to the extremes of a particular site. Observations by Parke *et al.* (1983) have shown the importance of temperature to indigenous mycorrhizal fungi and survival of outplanted seedlings. Fungi that can grow, even slowly, over a broad range of pH levels and temperature may be particularly useful in situations where soil conditions are unknown or may change during the growing period. The results of these experiments should be useful in selecting candidate fungi for mycorrhizal synthesis and subsequent outplanting trials.

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Table 1. Minimum, maximum and optimum temperatures and pH levels for growth of ectomycorrhizal fungi.

Fungi	pH			Temperature (°C)		
	minimum	optimum	maximum	minimum	optimum	maximum
Agaricus augustus	4	5	6	10	25	25
A. silvaticus	4	5-6	6	5	15-20	25
Amanita muscaria	3	6	7	5	25	25
A. porphyria	4	5	6	10	15-25	25
A. silvicola						
Isolate J96	3	6	6	15	25	25
Isolate J268	4	5	6	15	20	25
Armillaria ponderosa						
Isolate J107	3	5-6	7	15	20	25
Isolate J120	3	6	6	10	20	25
Isolate J169	3	6	8	5	15-25	25
A. zelleri						
Isolate J89	3	5	7	5	20	25
Isolate J144	3	6	7	5	20	25
Isolate J259	3	5-6	7	5	20	25
Bankera fuligineo-alba	3	5	7	10	15-20	25
Boletus chrysenteron	3	6	6	15	20	25
B. zelleri	3	5	6	5	20	25
Cenococcum geophilum						
Isolate J223	3	5	6	10	25	30
Isolate J329	3	5	6	10	20	25
Clitocybe nebularis						
Isolate J185	3	6	9	5	20	25
Isolate J291	4	6	9	5	20	25
Clitocybe suaveolens	4	6	9	5	20	30
Cortinarius violaceus	3	6	7	5	15-25	30
Hebeloma crustuliniforme						
Isolate J18	3	6	9	5	20-25	30
Isolate J90	4	6	8	10	25	25
Isolate J168	4	6-7	9	10	25	30
Hygrophorus agathosmus	5	6	7	5	20	20
Hygrophorus eburneus	4	7	8	5	20	25

Table 1. (continued)

Fungi	pH			Temperature (°C)		
	minimum	optimum	maximum	minimum	optimum	maximum
Laccaria laccata						
Isolate J45	3	7	8	5	20	25
Isolate J68A	3	7	8	5	20-25	30
Isolate J68B	3	6	8	5	20-25	25
Isolate J233	4	6	7	5	20-25	25
Isolate J330	4	7	8	10	20-25	25
Lactarius chelidonius	4	6	7	10	25	30
L. deliciosus						
Isolate J29	3	6	7	10	25	30
Isolate J103	3	5	7	15	20-25	25
L. rufus	3	5	6	5	20-25	25
L. sanguifluus	4	5	6	15	20	25
L. uvidus	3	5-7	9	5	20	25
Lycoperdon marginatum	4	4-6	7	5	25	30
L. perlatum						
Isolate J167	3	6	7	5	25	30
Isolate J209	4	5-6	6	5	25	30
Rhizopogon rubescens	3	5-6	6	15	25	25
R. vinicolor	2	4-5	6	5	20-25	25
R. vulgaris	3	5-6	7	5	25	30
Russula brevipes	3	6	8	5	25	25
Scleroderma bovista	3	6	6	5	25	25
Sphaerosporella brunnea						
Isolate J228	3	4-5	8	5	30	35
Isolate J328	3	5-6	8	5	30	35
Stropharia ambigua	3	6	8	5	20	25
Suillus albidipes						
Isolate J229	3	6	7	15	25	25
Isolate J237	3	3-5	6	10	25	25
S. brevipes						
Isolate J72	3	4-6	6	15	20	25
Isolate J222	2	6	8	5	25	25
Isolate J227	3	4-5	6	10	25	30
Isolate J256	3	4-6	6	5	25	30
S. granulatus	3	6	6	10	25	25

Table 1. (continued)

Fungi	pH			Temperature (°C)		
	minimum	optimum	maximum	minimum	optimum	maximum
Suillus lakei						
Isolate J77	3	4-6	7	5	20	25
Isolate J78	3	4-6	6	5	20	25
Isolate J85	3	4-6	7	10	20	30
Isolate J193	3	4-6	6	5	15-25	25
Isolate J213	3	4-6	6	5	20	25
S. luteus	3	6	6	15	20-25	25
S. tomentosus						
Isolate J138	2	4	7	10	25	30
Isolate J249	2	6	6	5	25	30
Isolate J275	2	4-6	7	5	25	25
Tricholoma pessundatum						
Isolate J207	3	4-6	7	5	20	30
Isolate J244	3	5-6	7	5	25-30	30
Truncocolumella citrina	3	4-6	6	10	20	25

Appendix 1

Identity and origin of the fungi tested for growth response to pH and temperature

Fungi	Isolate number	Year isolated	Origin and tree association (s)*
Agaricus augustus Fr.	J172	1979	Vancouver Island, Goldstream Park Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)
A. silvaticus Vitt ex Fr.	J84	1978	Vancouver Island, Parksville Douglas-fir
Amanita muscaria (Fr.) S.F. Gray	J87	1978	Vancouver Island, Victoria watershed Douglas-fir/western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) mix
A. porphyria (Alb. and Schw. ex Fr.) Secr.	J47	1976	Vancouver Island, Sooke western hemlock
A. silvicola Kauf.	J96	1978	Vancouver Island, Sooke mixed conifers
	J268	1980	Williams Lake lodgepole pine (*Pinus contorta* Dougl.)/Douglas-fir
Armillaria ponderosa	J107	1978	Vancouver Island, Sooke lodgepole pine
	J120	1978	Vancouver Island, Sooke lodgepole pine
	J169	1979	C.S. Bledsoe, locality and tree unspecified
A. zelleri Stuntz and Smith	J89	1978	Vancouver Island, Victoria watershed mixed conifers
	J144	1975	Alberta, R.M. Danielson #2479 jackpine (*Pinus contorta* Dougl. var. latifolia Engelm.)
	J259	1976	Alberta — R.M. Danielson #2491 jackpine
Bankera fuligineo-alba (Schmidt) Coker and Beers	J234	1976	Alberta, R.M. Danielson #2192 jackpine
Boletus chrysenteron Fr.	J171	1979	Vancouver Island, Goldstream Park western red cedar (*Thuja plicata* Donn)
B. zelleri Murr.	J76	1976	Vancouver Island, Beaver Lake mixed conifer forest
Cenococcum geophilum Fr.	J223	1975	Alberta jackpine
	J329	1981	Oregon, U.S.A.

Appendix I (continued)

Clitocybe nebularis (Fr.) Kummer	J291	1980	Vancouver Douglas-fir
	J185	1979	Vancouver Island Douglas-fir solitary
Clitocybe suaveolens (Fr.) Kummer	J206	1979	Vancouver Island — Campbell River Douglas-fir
Cortinarius violaceus (Fr.) S.F. Gray	J12	1974	Vancouver Island western hemlock
Hebeloma crustuliniforme (Bull. ex Saint-Amans) Quel.	J18	1974	Vancouver Island — Sooke Douglas-fir
	J90	1978	Vancouver Island — Victoria watershed Douglas-fir
	J168	1979	C.S. Bledsoe Locality and trees unspecified
Hygrophorus agathosmus Fr.	J116	1978	Vancouver Island — Goldstream Douglas-fir
H. eburneus (Fr.) Fries	J190	1979	Vancouver Island — Spectacle Lake mixed conifers
Laccaria laccata (Scop.: Fr.) Berk. & Br.	J45	1976	Vancouver Island — Sooke western hemlock
	J68A	1976	Vancouver Island — Cowichan mountain hemlock-(*Tsuga mertensiana* (Bong.) Carr.)
	J68B	1976	Vancouver Island — Cowichan mountain hemlock-fir
	J233	1978	Alberta jackpine
	J330	1978	Oregon, U.S.A. western larch (*Larix occidentalis* Nutt.)
Lactarius chelidonius Peck	J239	1976	Alberta jackpine
L. deliciosus (Fr.) S.F. Gray	J29	1975	Vancouver Island — Victoria watershed Douglas-fir
	J103	1978	Vancouver Island — Victoria watershed Douglas-fir
L. rufus (Scop. ex Fr.) Fries	J226	1979	Alberta jackpine
L. sanguifluus Fr.	J204	1979	Vancouver Island — Campbell River Douglas-fir
L. uvidus (Fr.) Fries	J95	1978	Vancouver Island — Sooke Douglas-fir

Appendix 1 (continued)

Lycoperdon marginatum Vitt.	J254	1980	Alberta jackpine
Lycoperdon perlatum Pers	J167	1979	Vancouver Island — Campbell River spruce (*Picea sitkensis* (Bong.) Carr.) lodgepole pine
	J209	1979	Vancouver Island — Campbell River Douglas-fir
Rhizopogon rubescens Tul.	J240	1976	Alberta jackpine
R. vinicolor Smith	J37	1976	Oregon, U.S.A. Douglas-fir
R. vulgaris (Vitt.) Lange	J338	1982	South Africa Monterey pine (*Pinus radiata* D. Don)
Russula brevipes Pk.	J279	1980	Vancouver Island — Victoria lodgepole pine
Scleroderma bovista Fr.	J49	1976	Vancouver Island — Victoria lodgepole pine
Sphaerosporella brunnea (Alb. and Schw. ex Fr.) Svrcek and Kubicka	J228	1980	Alberta jackpine
	J231	1980	Alberta jackpine
Stropharia ambigua (Pk.) Zeller	J23	1975	Vancouver Island — Victoria Douglas-fir
Suillus albidipes (Pk.) Singer	J229	1979	Alberta jackpine
	J237	1976	Alberta jackpine
S. brevipes (Pk.) Kuntze	J72	1976	Vancouver Island — Victoria lodgepole pine
	J222	1979	Alberta jackpine
	J227	1979	Alberta jackpine
	J256	1978	Alberta jackpine
S. granulatus (Fr.) Kuntze	J235	1977	Alberta jackpine

Appendix 1 (continued)

S. lakei (Murr.) Smith and Thiers	J77	1976	Vancouver Island — Beaver Lake mixed conifers
	J78	1976	Vancouver Island — Thetis Lake mixed conifers
	J85	1978	Vancouver Island Douglas-fir
	J193	1979	Vancouver Island — Gold River Douglas-fir
	J213	1979	Vancouver Island — Victoria Douglas-fir
S. luteus (Fr.) S.F. Gray	J211	1979	Vancouver Island — Victoria western white pine (*Pinus monticola* Dougl.)
S. tomentosus (Kauf.) Snell, Singer and Dick	J138	1979	Alberta lodgepole pine-Douglas-fir
	J249	1979	Alberta jackpine
	J275	1980	Williams Lake lodgepole pine
Tricholoma pessundatum (Fr.) Quel.	J207	1978	Vancouver Island — Campbell River Douglas-fir
	J244	1978	Alberta jackpine
Truncocolumella citrina Zeller	J33	1975	Vancouver Island — Victoria watershed Douglas-fir/western hemlock

* Predominant tree species in the forest stand and nearest to the isolation sporocarp.

Appendix II

Growth diameter (mm) of ectomycorrhizal fungi on a modified Melin-Norkrans medium adjusted to various pH levels

Fungi	pH 2	3	4	5	6	7	8	9
Agaricus augustus	0	0	7a	9b	7a	0	0	0
A. silvaticus	0	0	4a	8b	8b	0	0	0
Amanita muscaria	0	3a	6b	7c	8d	4a	0	0
A. porphyria	0	0	4a	7b	4a	0	0	0
A. silvicola								
Isolate J96	0	3a	7b	8c	10d	0	0	0
Isolate J268	0	0	9a	9a	6b	0	0	0
Armillaria ponderosa								
Isolate J107	0	2a	7b	9c	9c	3a	0	0
Isolate J120	0	4a	6b	8c	10d	0	0	0
Isolate J169	0	3a	6b	7b	8c	1d	1d	0
A. zelleri								
Isolate J89	0	3a	16b	20c	11d	3a	0	0
Isolate J144	0	7a	10b	10b	12c	3d	0	0
Isolate J259	0	6a	13b	16c	15c	3d	0	0
Bankera-fuligineo-alba	0	7a	11b	13c	10b	3d	0	0
Boletus chrysenteron	0	1a	5b	6c	7d	0	0	0
B. zelleri	0	11a	16b	18c	14d	0	0	0
Cenococcum geophilum								
Isolate J223	0	5a	7b	9c	6d	0	0	0
Isolate J329	0	3a	7b	10c	7b	–	0	0
Clitocybe nebularis								
Isolate J183	0	7a	25b	38c	41d	15e	15e	15e
Isolate J291	0	0	20a	24b	34c	15d	18e	12f
C. suaveolens	0	0	16a	27b	36c	33d	24e	18f
Cortinarius violaceus	0	8a	14b	23c	42d	7a	0	0
Hebeloma crustuliniforme								
Isolate J18	0	3a	11b	11b	14c	12b	10d	8e
Isolate J90	0	0	3a	6b	9c	8d	7b	0
Isolate J168	0	0	5a	7b	10c	10c	7b	6a
Hygrophorus agathosmus	0	0	0	6a	8b	3c	0	0
H. eburneus	0	0	6a	13b	24c	27d	12d	0

Appendix Ii (continued)

Fungi	pH 2	3	4	5	6	7	8	9
Laccaria laccata								
Isolate J45	0	5a	12b	18c	25d	29e	18c	0
Isolate J68A	0	4a	11b	24c	31d	38e	26f	0
Isolate J68B	0	6a	16b	23c	37d	34e	18f	0
Isolate J233	0	0	3a	13b	17c	5d	0	0
Isolate J330	0	0	7a	15b	28c	30d	14b	0
Lactarius chelidonius	0	0	5a	7b	10c	5a	0	0
L. deliciosus								
Isolate J29	0	3a	8b	12c	16d	8b	0	0
Isolate J103	0	3a	6b	9c	6b	3a	0	0
L. rufus	0	10a	20b	21c	13d	0	0	0
L. sanguifluus	0	0	1a	8b	5c	0	0	0
L. uvidus	0	13a	18b	21c	21c	22c	19d	17e
Lycoperdon marginatum	0	0	12a	18b	19b	7c	0	0
L. perlatum								
Isolate J167	0	3a	17b	21c	27d	12e	0	0
Isolate J209	0	0	14a	22b	21b	8c	0	0
Rhizopogon rubescens	0	16a	20b	22c	23c	0	0	0
R. vinicolor	4a	17b	20c	21c	17b	0	0	0
R. vulgaris	0	18a	20a	26b	27b	3c	0	0
Russula brevipes	0	20a	29b	33c	39d	8e	3f	0
Scleroderma bovista	0	1a	9b	12c	15d	0	0	0
Sphaerosporella brunnea								
Isolate J228	0	40a	42b	42b	42b	35c	6d	3e
Isolate J231	0	27a	39b	42c	42c	14d	2e	0
Stropharia ambigua	0	9a	18b	25c	36d	29e	8f	0
Suillus albidipes								
Isolate J229	0	20a	23b	27c	31d	3e	0	0
Isolate J237	0	16a	17a	16a	10b	0	0	0
S. brevipes								
Isolate J72	0	11a	12b	11ab	12b	0	0	0
Isolate J222	3d	17a	22b	25b	28c	3d	3d	0
Isolate J227	0	19a	20ab	22b	18a	0	0	0
Isolate J256	0	12a	17b	15c	18b	0	0	0

Appendix II (continued)

Fungi	pH 2	3	4	5	6	7	8	9
S. granulatus	0	15a	20b	23c	27d	0	0	0
S. lakei								
Isolate J77	0	13a	16b	14a	17b	1c	0	0
Isolate J78	0	5a	8b	9b	8b	0	0	0
Isolate J85	0	16ab	18a	15b	18a	4c	0	0
Isolate J193	0	14a	18b	18b	16ab	0	0	0
Isolate J213	0	12a	15b	14c	15b	2d	0	0
S. luteus	0	13a	17b	18b	20c	0	0	0
S. tomentosus								
Isolate J138	4a	12b	14c	12b	13b	3a	0	0
Isolate J249	3a	12b	13bc	14c	16d	0	0	0
Isolate J275	3a	17b	13c	14bc	16bc	2a	0	0
Tricholoma pessundatum								
Isolate J207	0	3a	14b	21b	24b	3a	0	0
Isolate J244	0	10a	11a	16b	17b	4c	0	0
Truncocolumella citrina								
Isolate J33	0	15a	18ab	20b	16ab	0	0	0

* Reading across, means followed by a common letter do not differ significantly ($p = 0.05$)

Appendix III

Growth diameter (mm) of ectomycorrhizal fungi on a modified Melin-Norkrans medium at different incubation temperatures

Fungi	Incubation temperatures (°C)					
	5	10	15	20	25	30
Agaricus augustus	0	4a	8b	12c	13d	0
A. silvaticus	2a	2a	8b	9b	5c	0
Amanita muscaria	2a	3ab	2a	3ab	4a	0
A. porphyria	0	1a	4b	4b	5b	0
A. silvicola						
Isolate J96	0	0	6a	10b	12c	0
Isolate J268	0	0	5b	8b	1c	0
Armillaria ponderosa						
Isolate J107	0	0	3a	5b	5c	0
Isolate J120	0	3a	6b	6c	4d	0
Isolate J169	2a	3a	4b	6b	6b	0
A. zelleri						
Isolate J89	2a	6b	13c	18d	3a	0
Isolate J144	2a	3ad	7b	11c	4d	0
Isolate J259	6a	10ab	16bc	20c	8a	0
Bankera fuligineo-alba	0	2a	4b	4b	3a	0
Boletus chrysenteron	0	0	7a	13b	10c	0
B. zelleri	2a	5b	11c	13d	4b	0
Cenococcum geophilum						
Isolate J223	0	3a	7b	11c	13d	7b
Isolate J329	0	3a	6b	8c	6b	0
Clitocybe nebularis						
Isolate J185	1a	5b	21c	25d	5b	0
Isolate J291	14a	19b	37c	39d	11e	0
C. suaveolens	6a	16b	30c	34d	24e	3f
Cortinarius violaceus	6a	14b	35c	40c	37c	2a
Hebeloma crustuliniforme						
Isolate J18	1a	3b	11c	14d	13cd	1a
Isolate J90	0	3a	6b	6c	7d	0
Isolate J168	0	3a	2b	3ab	4c	3a
Hygrophorus agathosmus	3a	3a	7b	7c	0	0
H. eburneus	4a	14b	15b	20c	11d	0

Appendix III (continued)

Fungi	Incubation temperatures (°C)					
	5	10	15	20	25	30
Laccaria laccata						
Isolate J45	2a	9b	17c	23d	22e	0
Isolate J68A	2a	11b	22c	30d	29d	1a
Isolate J68B	1a	9b	18c	23d	22d	0
Isolate J233	1a	4b	7c	11d	10d	0
Isolate J330	0	11a	22b	31c	32c	0
Lactarius chelidonius	0	3a	6b	11c	15d	9bc
L. deliciosus						
Isolate J29	0	3a	4a	8b	10c	1d
Isolate J103	0	0	2a	4b	4b	0
L. rufus	3a	4b	8c	12d	12d	0
L. sanguifluus	0	0	1a	6b	1a	0
L. uvidus	5a	9b	14c	20d	1e	0
Lycoperdon marginatum	3a	8b	14c	21d	24e	8b
Lycoperdon perlatum						
Isolate J167	3a	6b	14c	20d	30e	16f
Isolate J209	8a	12b	18c	35d	45e	3f
Rhizopogon rubescens	0	0	4a	8b	17c	0
R. vinicolor	2a	5b	9c	14d	13d	0
R. vulgaris	2a	7b	17c	25d	28e	27de
Russula brevipes	8a	14b	24c	35d	41e	0
Scleroderma bovista	1a	2b	4c	5c	6d	0
*Sphaerosporella brunnea***						
Isolate J228	1a	4b	12c	16d	26e	31f
Isolate J231	1a	5b	10c	13d	19e	23f
Stropharia ambigua	3a	16b	26c	30d	17b	0
Suillus albidipes						
Isolate J229	0	0	11a	22b	31c	0
Isolate J237	0	1a	4b	7c	14d	0
S. brevipes						
Isolate J72	0	0	6a	15b	3a	0
Isolate J222	3a	3a	3a	16b	29c	0
Isolate J227	0	3a	8b	17c	23d	2a
Isolate J256	3a	3a	8b	17c	23d	2a
S. granulatus	0	2a	4b	10c	26d	0

Appendix III (continued)

Fungi	Incubation temperatures (°C)					
	5	10	15	20	25	30
S. lakei						
Isolate J77	3a	3a	8b	18c	13d	0
Isolate J78	1a	1a	6b	9c	5d	0
Isolate J85	0	2a	3a	6b	2a	2a
Isolate J193	1a	4a	15b	20b	17c	0
Isolate J213	3a	5b	9c	14d	3d	0
S. luteus	0	0	11a	24b	27b	0
S. tomentosus						
Isolate J138	0	3a	3a	9b	13c	5d
Isolate J249	3a	5b	8c	12d	19e	3a
Isolate J275	3a	9b	11c	18d	30e	0
Tricholoma pessundatum						
Isolate J207	3ab	3ab	4a	6c	2b	3ab
Isolate J244	1a	1a	7b	10c	14d	18cd
Truncocolumella citrina	0	2a	3a	5b	3a	0

* Reading across, means followed by a common letter do not differ significantly (p = 0.05)

** Both isolates of *S. brunnea* grew at 35°C (J228 — 5b and J231 — 7g) but would not grow at 40°C.